Oct. 16-21, 2005 Wintergreen, VA, USA

Solar and Space Physics and the vision for Space Exploration

The Sun-Earth Connection of Major Geomagnetic Storms

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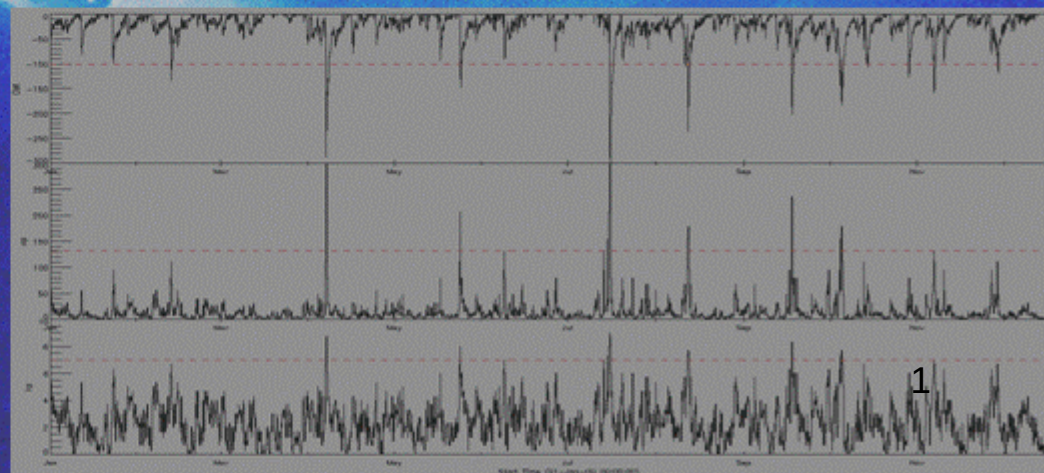
George Mason University

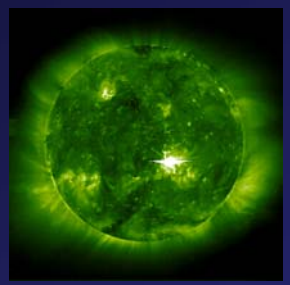


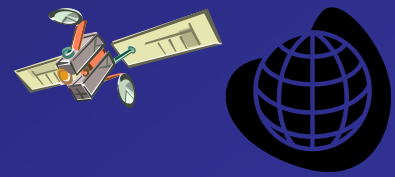
Event chain from Sun to Earth

CME
Flare
Coronal Dimming
Filament Eruption

ICME
CIR

Storms
In Geo.
Space





LASCO
EIT
MDI
(SOHO)
….

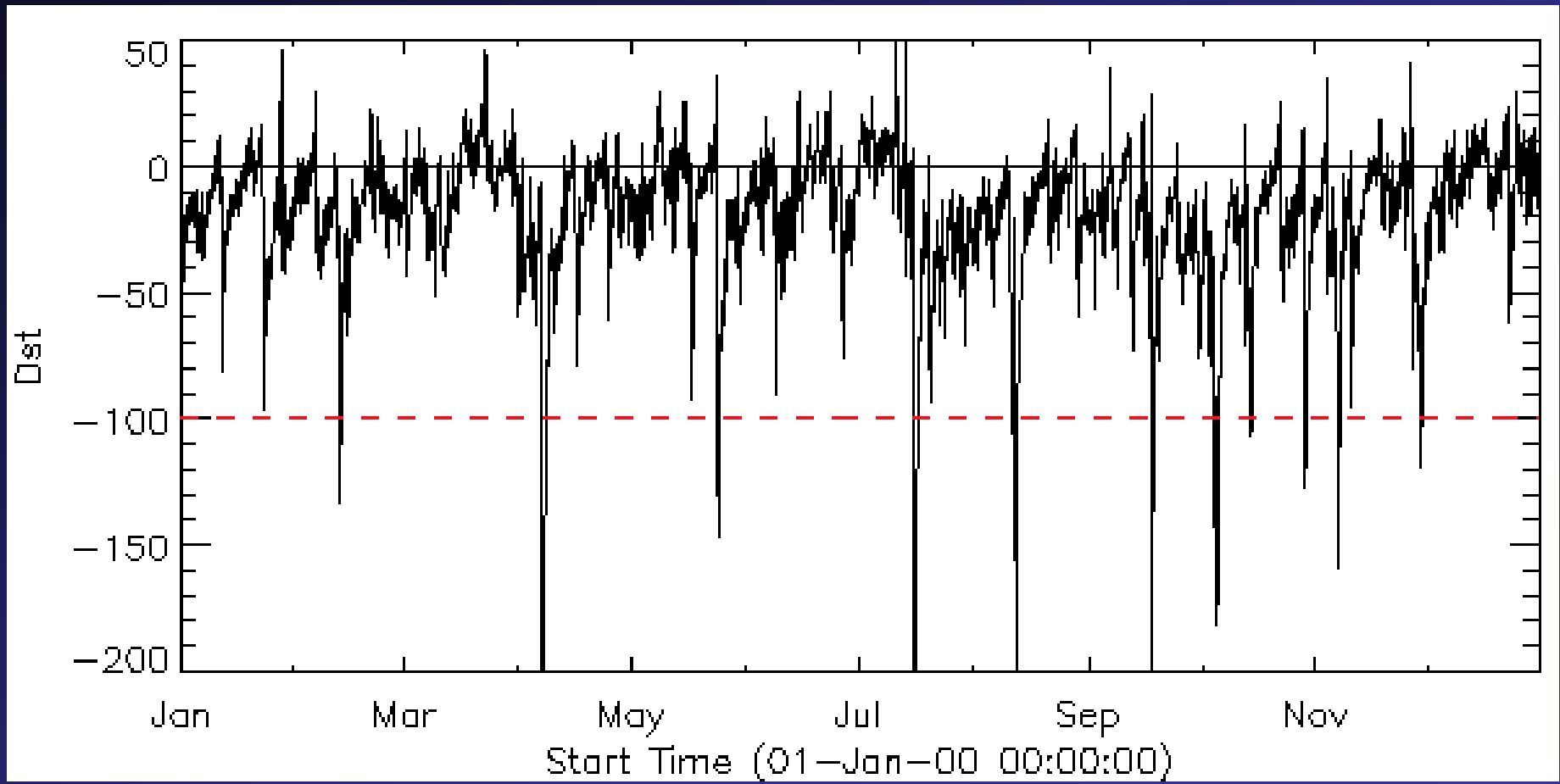
Lack of Observations

ACE
WIND

Dst
…..

Major Geomagnetic Storms

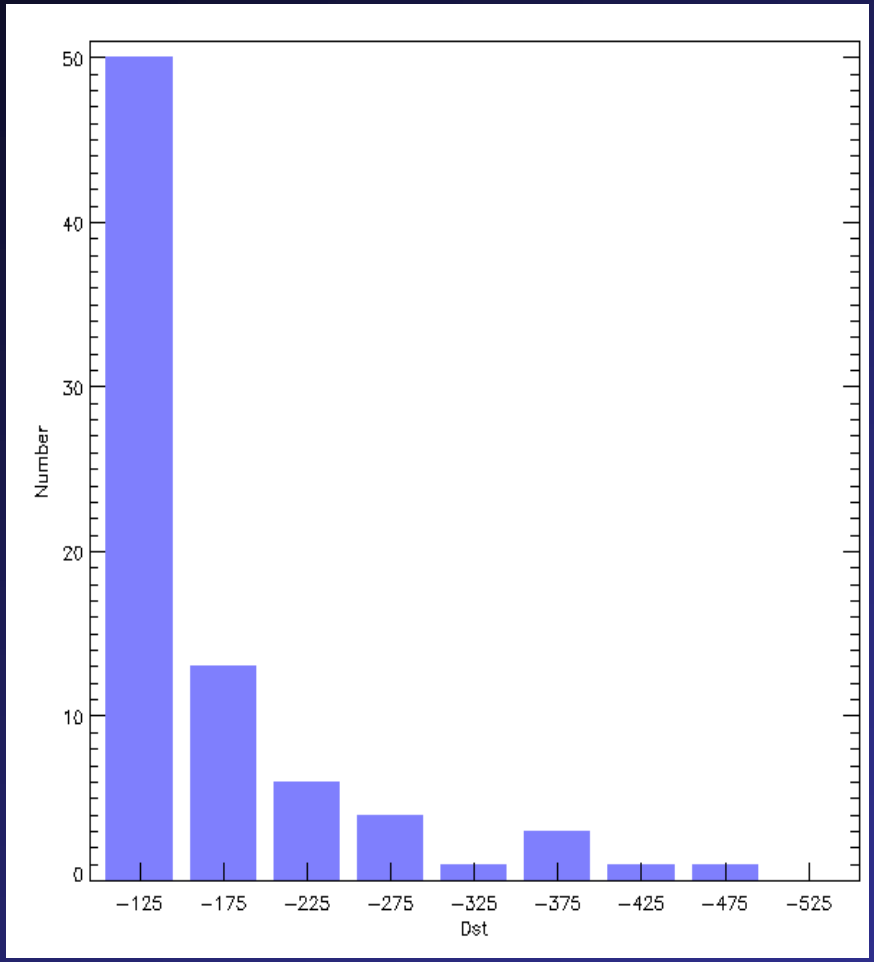
- Dst <= -100



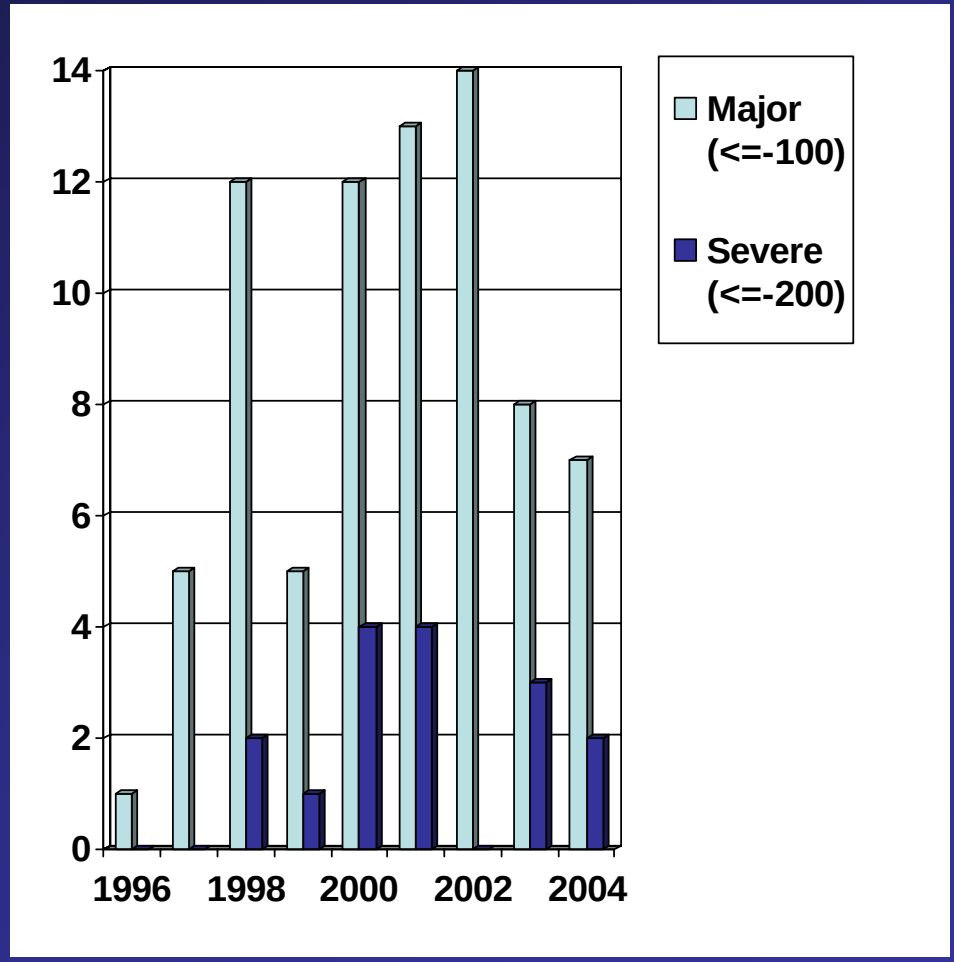
Dst index in 2000

Distribution of Major Storms (1996-2004)

- 79 major events (Dst <= -100)
- 16 severe events (Dst <= -200)



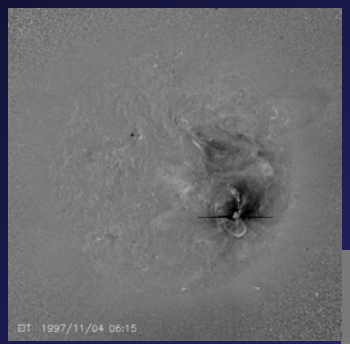
By Intensity

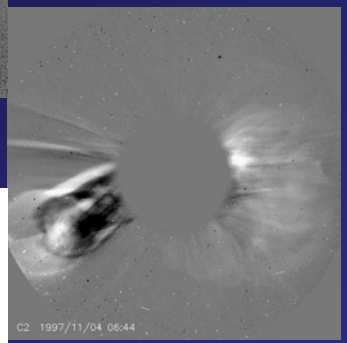


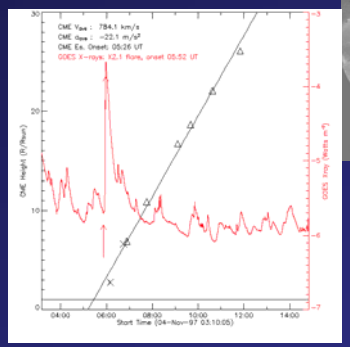
By Year

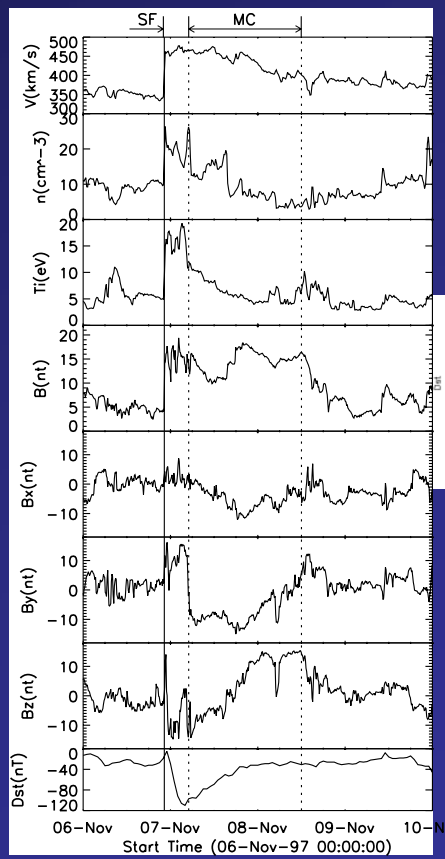
How to Find Solar Sources

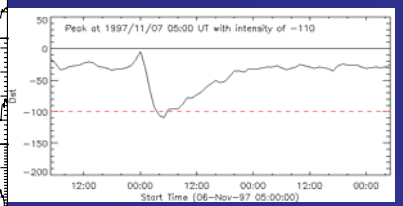
- **Step 1: set the 120-hr backward search window**
- **Step 2: find all halo CMEs in the window (AW >= 120)**
- **Step 3: find out front-side halo CMEs, and locate their source region**
- **Step 4: find a reduced adaptive search window using solar wind velocity jump (Zhang et al. 2003)**









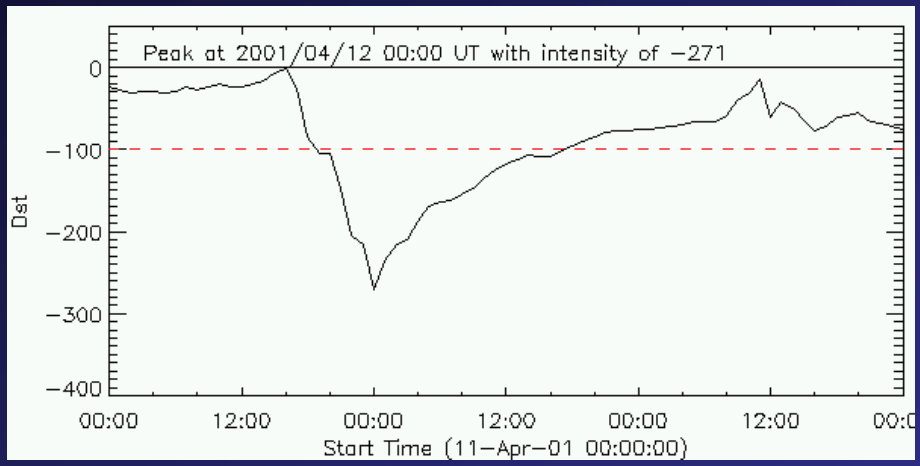


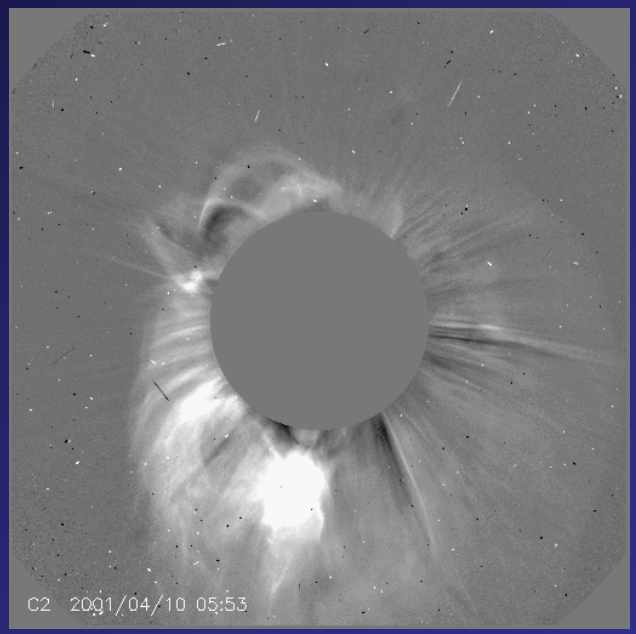
Three Types of Solar Drivers

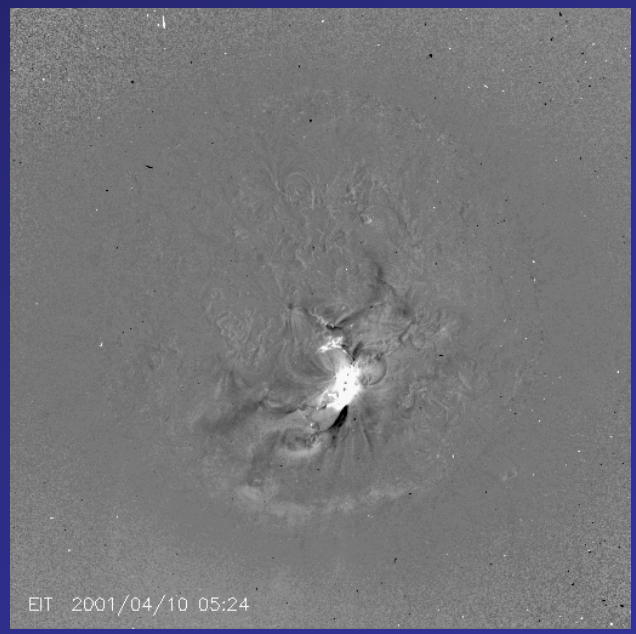
1. S Type: driven by a single CME
2. M Type: driven by multiple CMEs interacting in IP
3. C Type: driven by CIR from Coronal Hole

S Type Driver (example)

Dst peak at 2001/04/12 00:00 UT, driven by CME at 04/10 05:30 UT

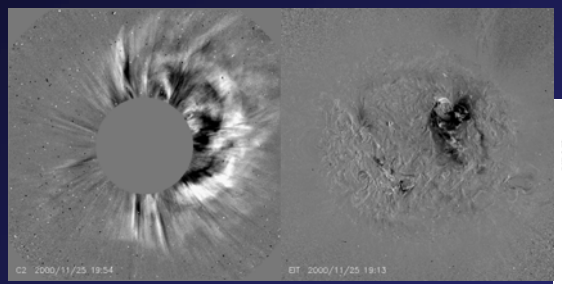


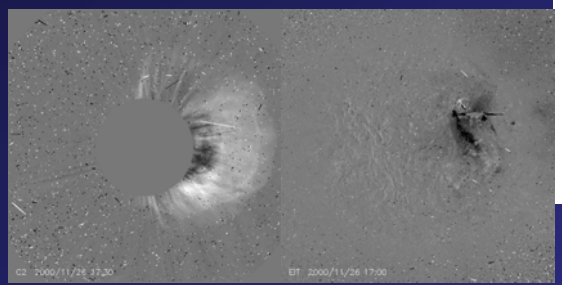


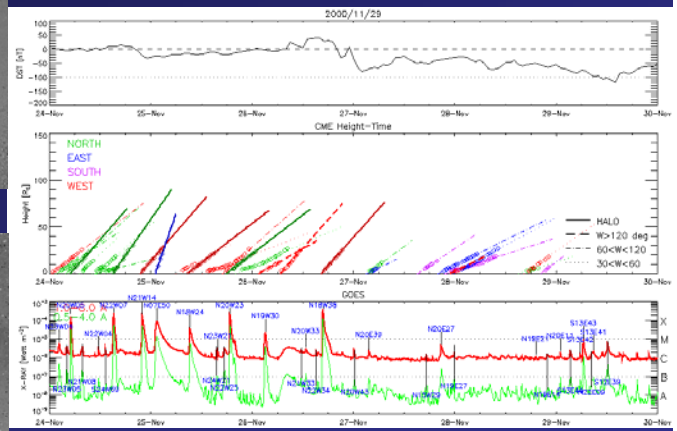


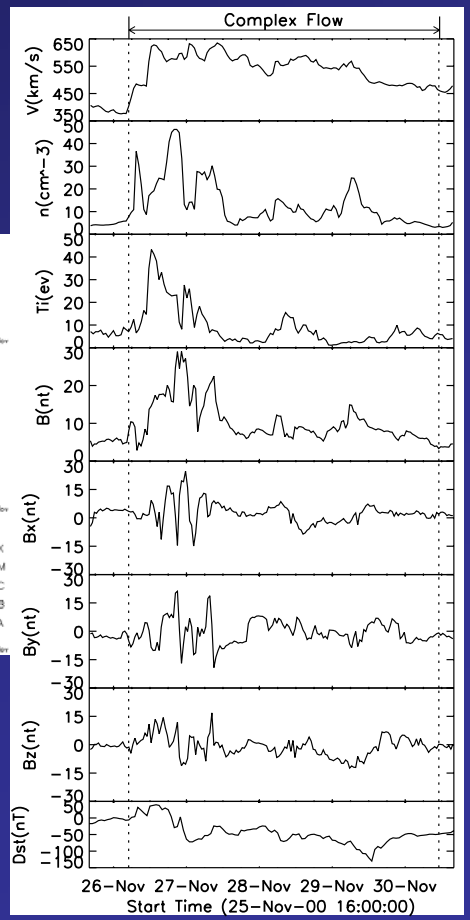
M Type Driver

- Complex Dst plot, multiple CMEs (and flares)
- Complex solar wind flow
- Consecutive CMEs from same active region



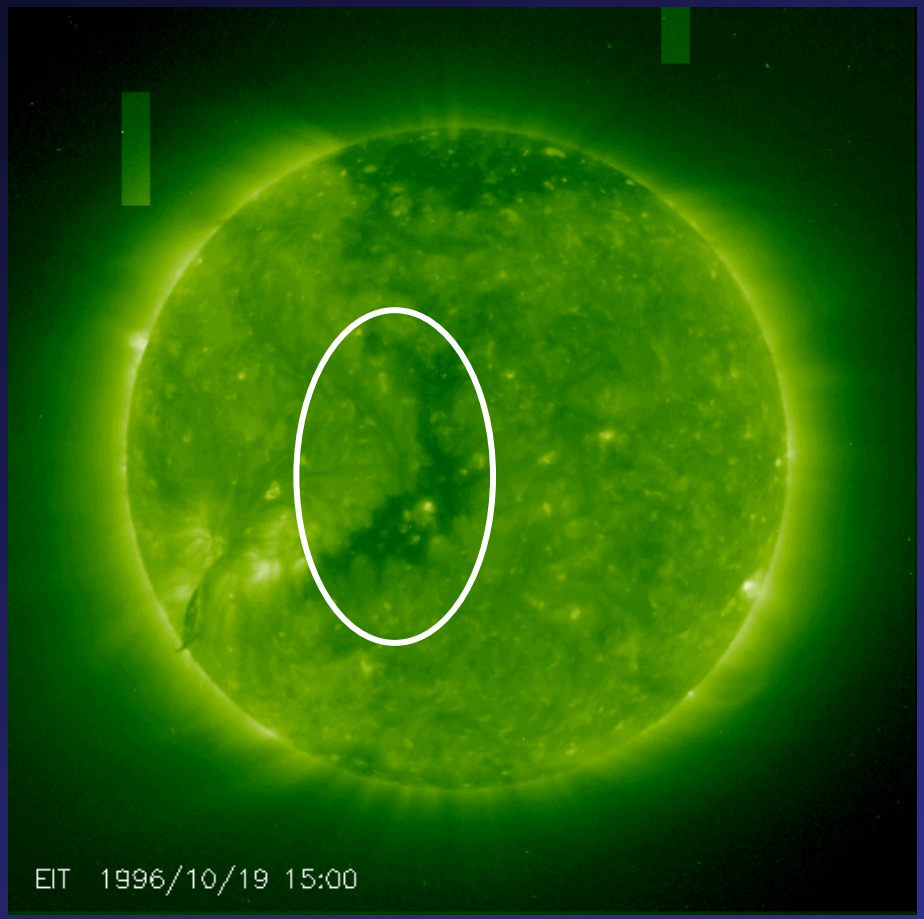


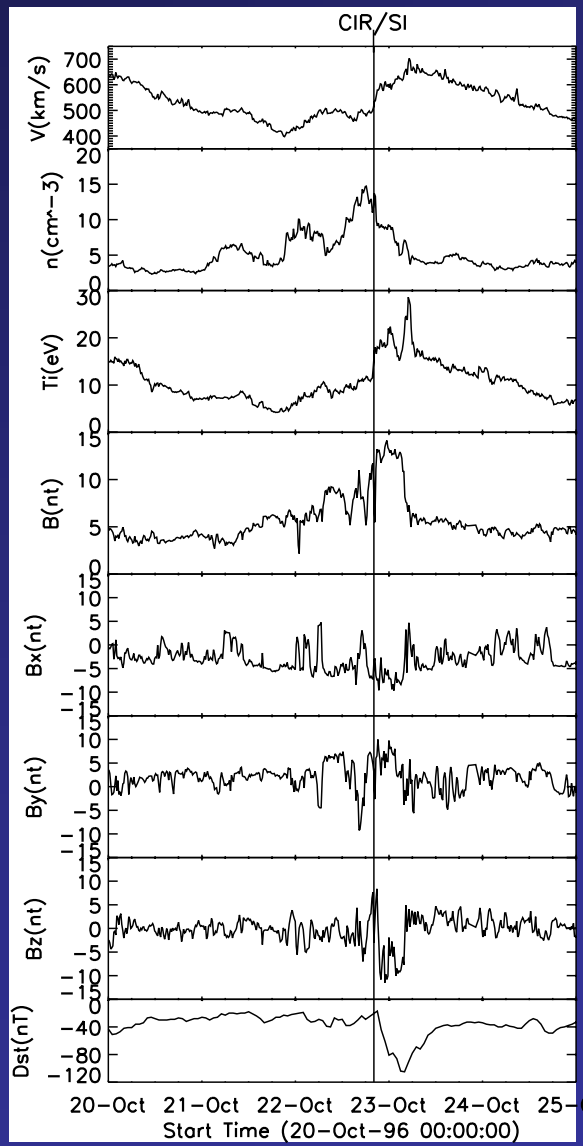




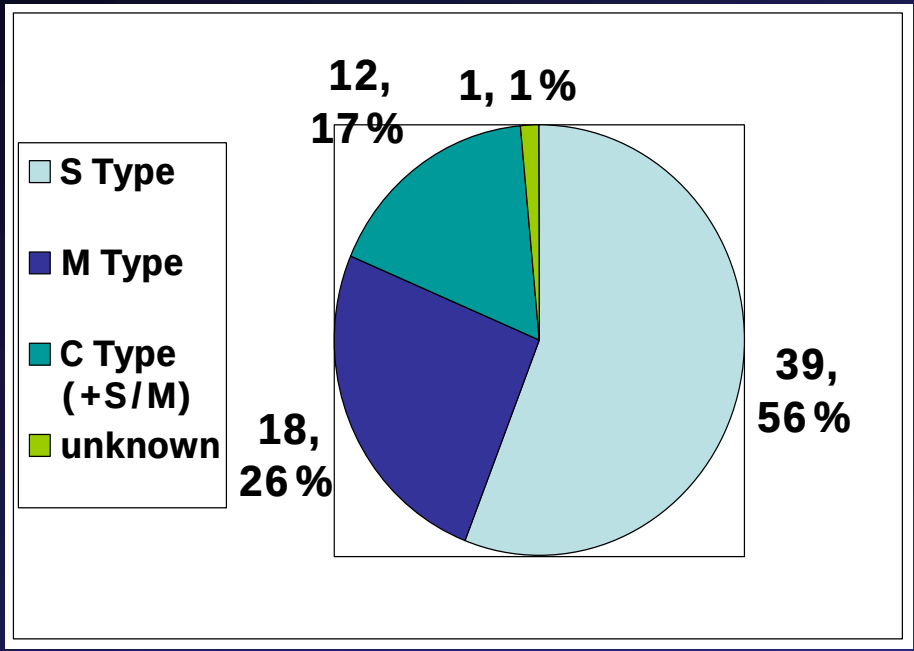
C Type Driver

- CIR (Corotation Interaction Region)
- Coronal Hole

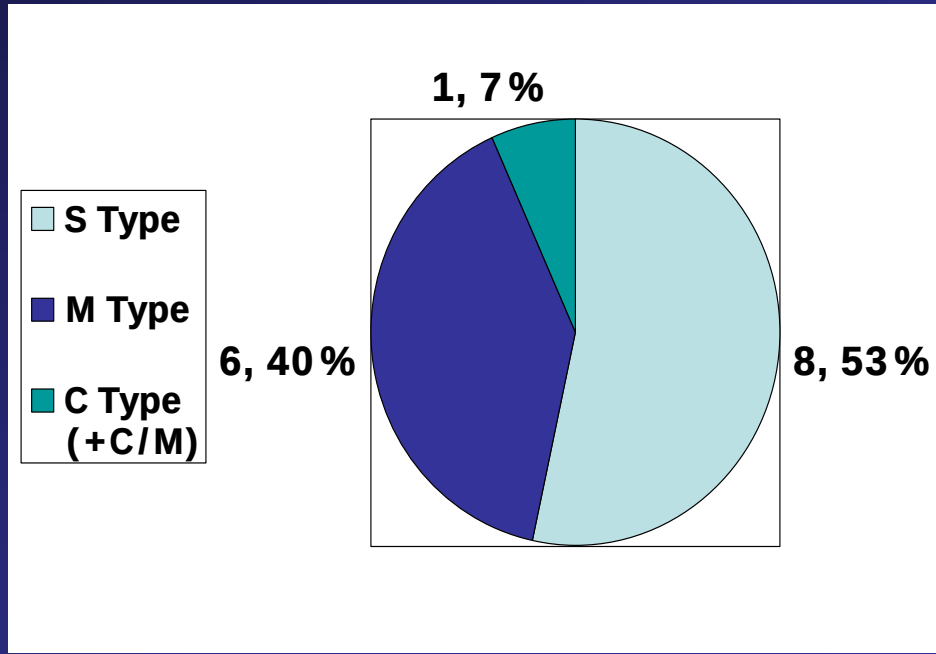




Solar Drivers of Major Storms

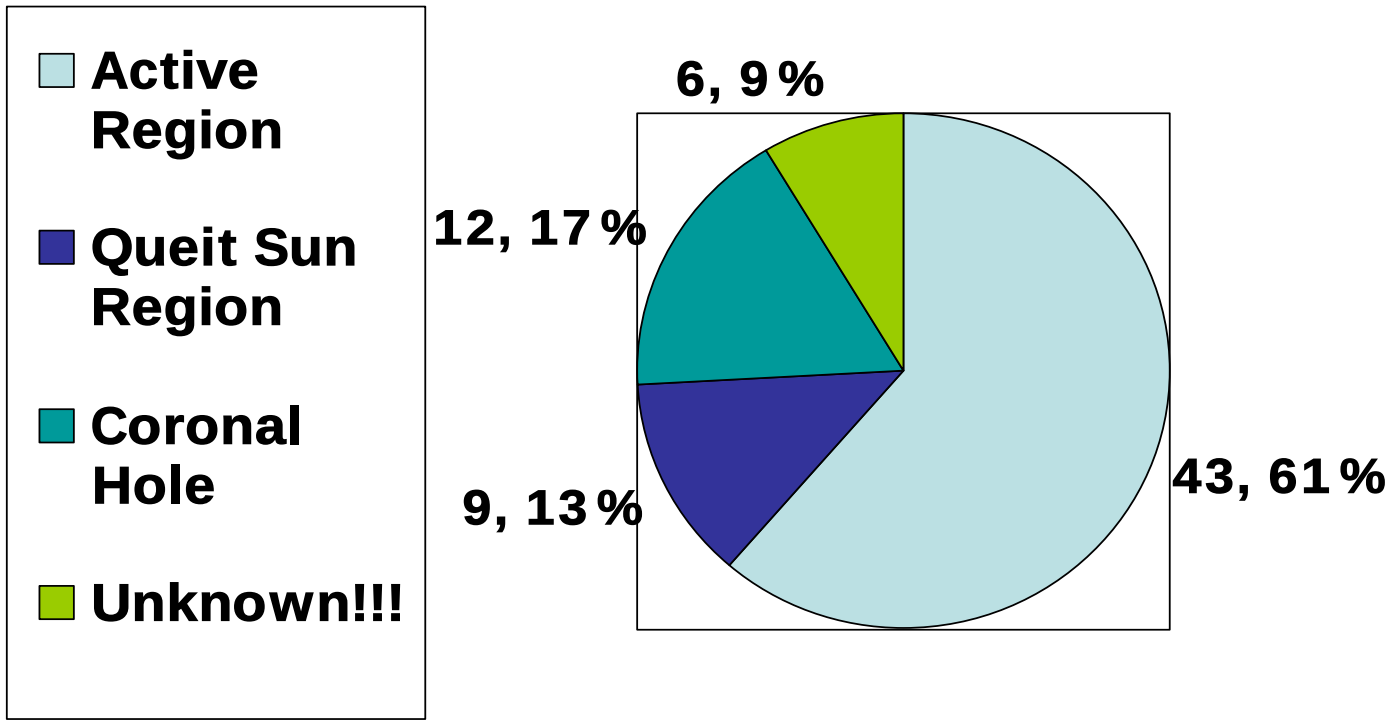


70 Major Storms
(excluding 9 in data gap)



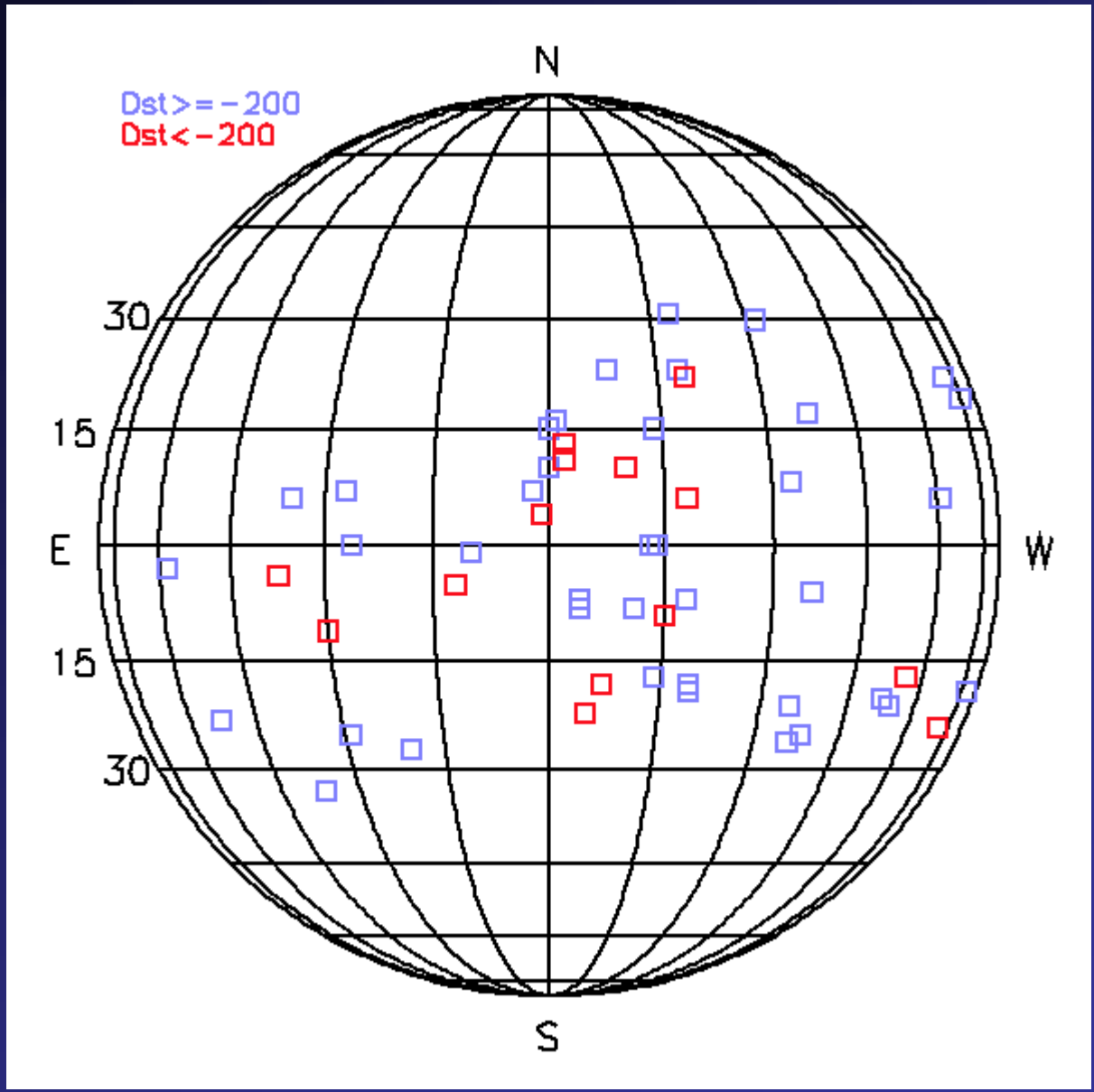
15 Severe Storms
(excluding 1 in data gap)

Source Regions of Major Storms

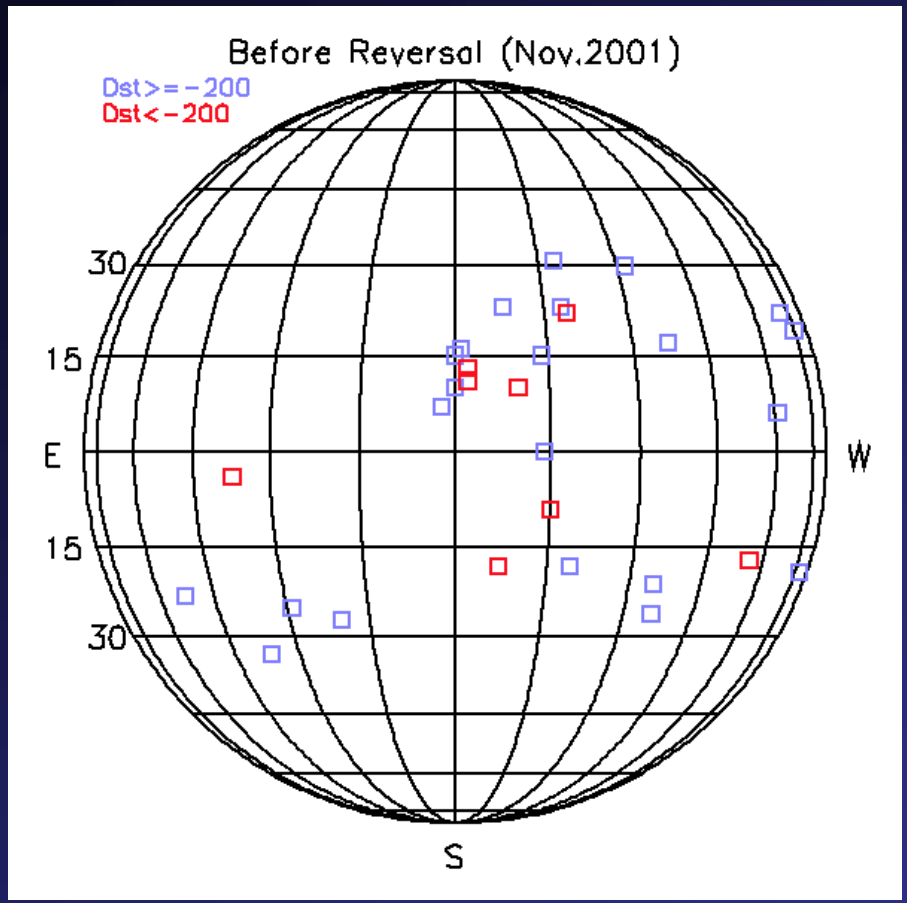


70 Major Storms

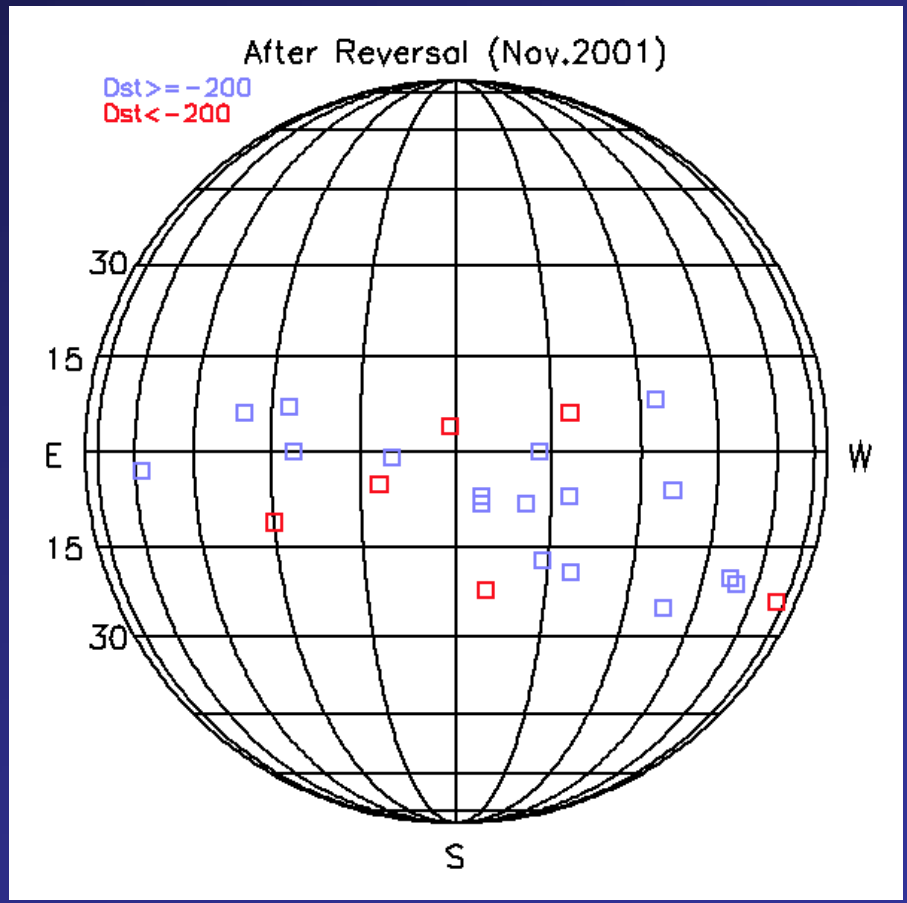
Source Region Distribution



Intra-Solar Cycle Variation of Source Regions



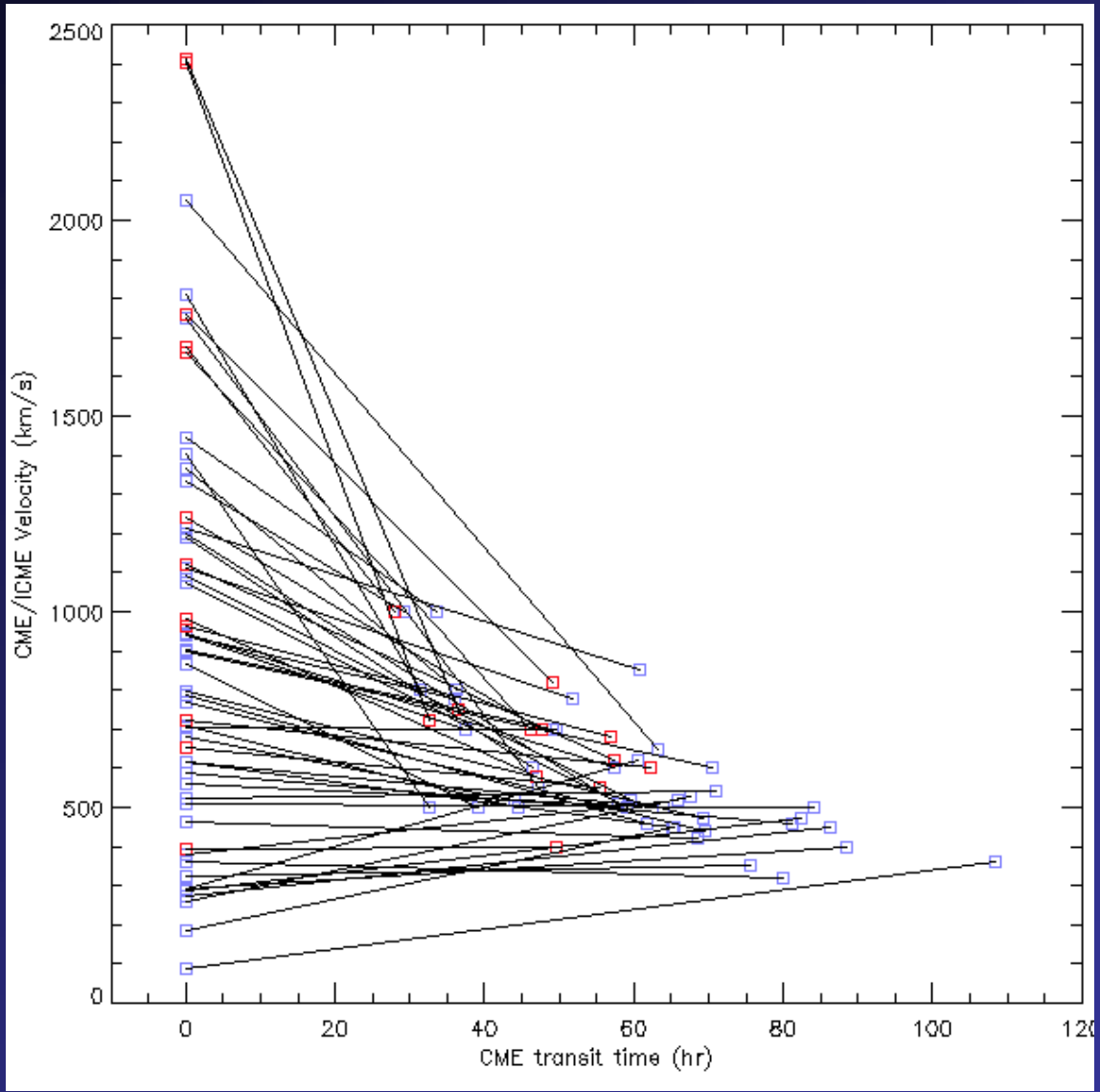
Before Polar Reversal



After Polar Reversal

Velocity of CME and ICME & Transit Time

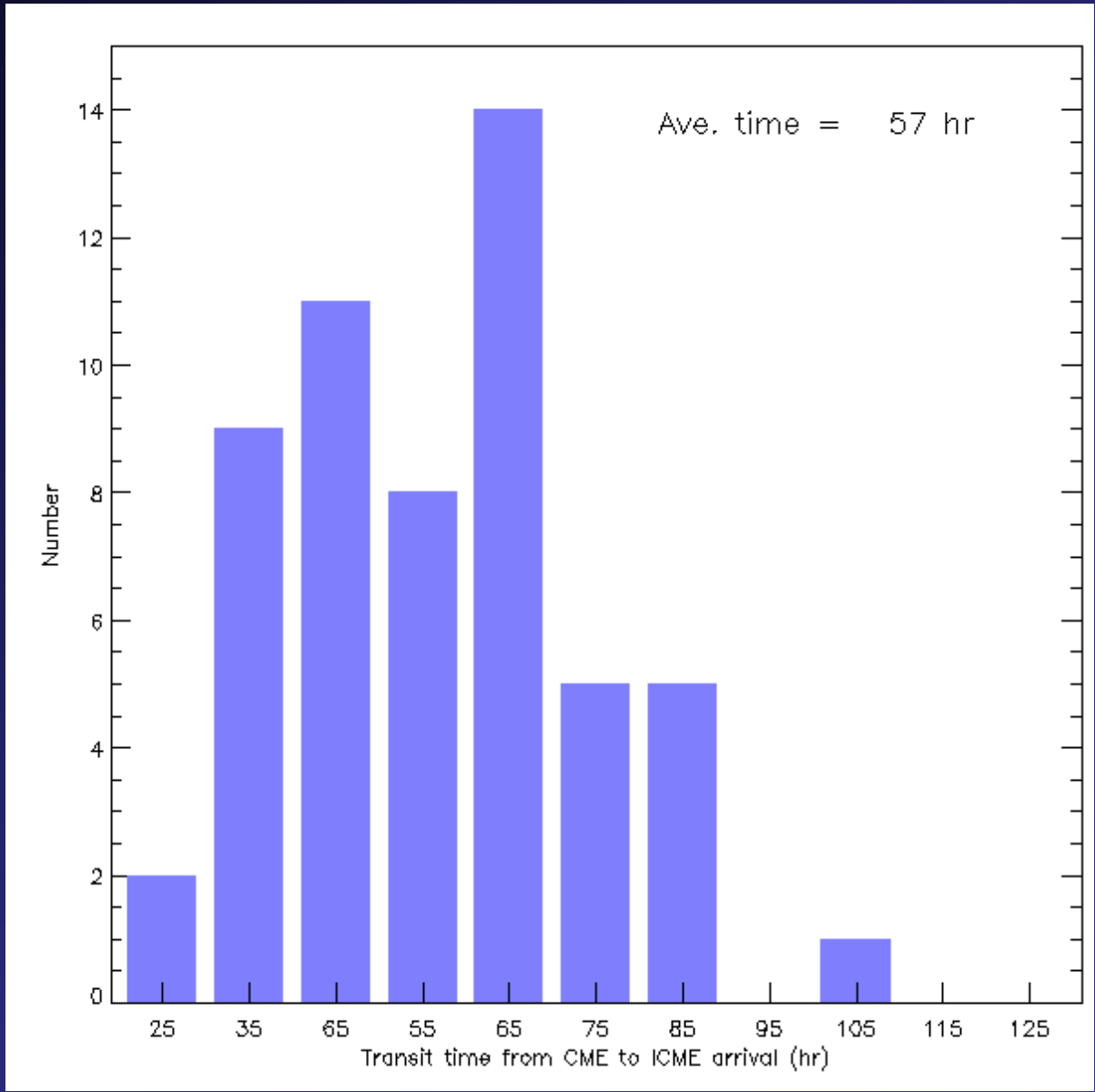
CME Velocity (km/s)



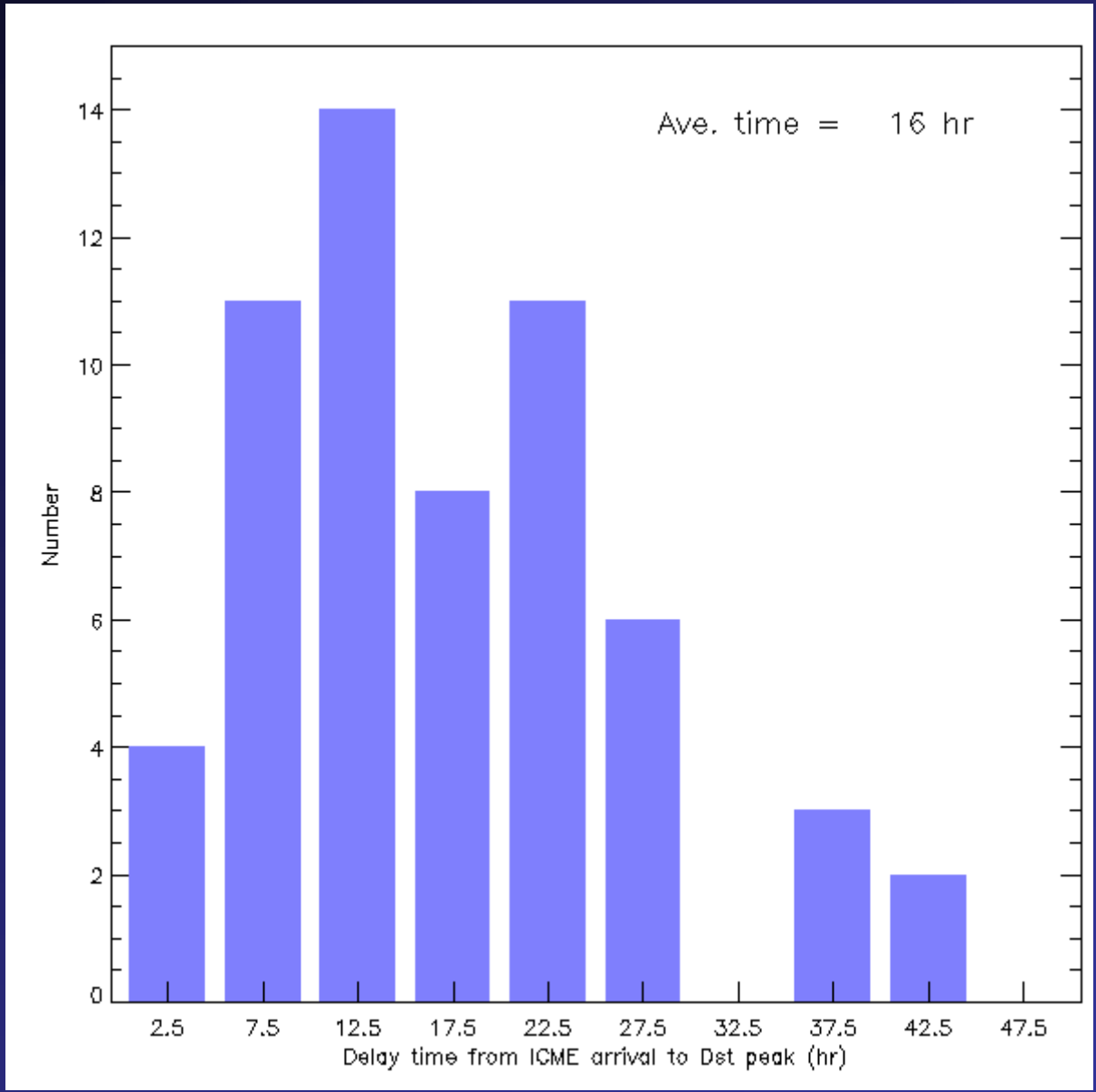
ICME Velocity (km/s)

CME Transit Time from Sun to Earth (hr)

CME Transit Time from the Sun to Earth



Delay Time Betw. ICME Arrival and Dst Peak



Discussion and Conclusion

- **Three Types of Solar Drivers**
  - **S Type: 56%**
  - **M Type: 26%**
  - **C Type: 17%**

- **Hemispheric Dependence on Solar Cycle**
  - **Western Hemisphere preferred for all phases**
  - **Explanation: west hemisphere connection due to spiral IP field**
  - **Northern Hemisphere preferred before polar field reversal**
  - **Southern Hemisphere preferred after polar field reversal**
  - **Explanation: Participation of global field in geo-effective Bz component**
  - **North-Eastern quadrant is un-favored for all phases in solar cycle 23**

- **Inner Heliospheric Observations are needed to identify the Sun-Earth-connection chain and predict the arrival time**